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REVIEWS

Geology of the Haliburton and Bancroft Areas, Providence of Ontario.

By FRANK D. ADAMS and ALFRED E. BARLOW. Ottawa:
Canada Department of Mines, Memoir No. 6. Pp. 419;
70 photographic illustrations, 7 figures, 2 maps.

The Haliburton and Bancroft areas described by Adams and Barlow are located in the southeastern part of Ontario within the Canadian Protaxis. They constitute a pre-Cambrian complex of about 4,200 square miles, of which the southern portion, the Bancroft area, consists mainly of limestone and dolomite, with minor clastic sediments, intruded by syenites, gabbros, and diorites, and intercalated with acid eruptives, the whole invaded by an enormous batholithic development of granite gneisses and granites, exposed mainly in the Haliburton area to the north, and making up more than half of the total extent of the region. This complex was intricately folded in pre-Cambrian times, mainly under conditions of flow contemporaneously with the intrusion of the granite gneisses and granites, the major axis of deformation being N. 30° E.

Like most of the Protaxis, this region is beveled by a nearly level plane of erosion whose inequalities result from etching and the unevenness of glacial deposition. Here and there monadnocks of igneous rock rise to a height of several hundred feet above their surroundings. To the south, this surface dips under nearly horizontal Paleozoic limestones beveled by a much smoother plain. The fertility and cultivation of the conspicuous, steep-faced outliers of Paleozoic limestones studding the boundary, contrast strikingly with the more sparsely settled, slightly tilted pre-Cambrian, much of which is a succession of low, rolling, barren knobs of rock rising from a boulder-strewn waste, whose drift and rock depressions are frequently occupied by lakes or swamps. Green, unbroken forests still withhold a portion of it from the desolateness to which it is doomed, a land in which canoe and trail are still necessities of travel. From the Paleozoic front, the undulating plain which bevels the pre-Cambrian rocks rises toward the northeast, with a gradient of about 8 feet per mile, to a wavy line of maximum elevation of about 1,500 feet trending a little south of east through the northern part of the

Haliburton area. From thence it descends toward the northeast, thus dividing the drainage to the south and west into the St. Lawrence system and to the north into the Ottawa River. Both the configuration of the lakes and the direction of the streams is guided to a large extent by the foliation of the rocks. This is especially true of the limestone area while the drainage lines on the granite gneisses show much less dependence on tectonic lines.

The limestones and dolomites of this region are a part of a pre-Cambrian limestone terrane stretching from Georgian Bay to beyond the St. Maurice River in the Province of Quebec. In the contiguous area to the southeast of the Haliburton and Bancroft areas, Logan's Hastings district, these limestones and dolomites, while containing basic intrusives, are less highly altered than in Logan's Original Grenville of Quebec, where they are intruded and intensely altered by the same granite gneisses which invade them in the Haliburton and Bancroft areas. Since the less altered limestones of the Hastings district grade into the highly altered limestones to the northwest without divergence of strike and without the interposition of basal conglomerates, or other evidences of unconformity, Adams and Barlow believe that the entire terrane constitutes one series to which they give the name Grenville, and with this they correlate the limestones of the Adirondacks, thus grouping as one, an areal exposure of 83,000 square miles of limestone, one of the greatest developments of limestones in North America, and the greatest in the pre-Cambrian. The existence of certain conglomerates in the Bancroft area, however, has caused Miller and other geologists to suspend judgment as to the unity of this region.

The position of the Grenville Hastings series in the pre-Cambrian is still left in doubt since they have not been found to connect with any of the correlated units. Nor do they resemble any of them lithologically. In the linear character of their topography and in their great dominance of sediments, they are more like the Algonkian than the Archean. Adams and Barlow class them as Archean, evidently using the term as synonymous with pre-Cambrian.

The basement on which the sediments rest has nowhere been found. Adams and Barlow, however, follow Lawson in their belief that in cases like this, the sediments were deposited on the granites and that later the granite basement became re-fused and intruded into the sediments.

The thickness of the sediments in the Haliburton and Bancroft areas is estimated by the authors to be about 17 miles, though they recognize the probability that isoclinal folding and other factors may

have added to the apparent thickness. One feels rather quizzical at the confidence with which they present this figure.

The least metamorphosed, pure limestones are mostly fine-grained, and of a bluish color, the dark color being due to organic matter. They are interstratified with dolomitic and magnesian beds, but the pure limestones dominate. This great development of pure limestones modifies the prevailing opinion that the pre-Cambrian does not contain many pure limestones.

The magnesium carbonate is found to occur in the mineral dolomite, and as a slight replacement of calcium carbonate in calcite. All gradations are also found, from pure limestones to argillaceous and quartz-bearing limestones and dolomites, quartzites and paragneisses, but the impure rocks are highly recrystallized as a rule. Most of the limestones and dolomites have been intensely metamorphosed, but the relative importance of intrusion and of intense folding in bringing this about is not always clear. The carbonates have adjusted themselves to stress strain conditions by plastic flow, including recrystallization, gliding, shearing, and granulation. In general the limestones were more plastic than the silicate or quartz rocks associated with them, flowing in between the fragments of the latter.

The most apparent effects of metamorphism on the limestones are a coarsening of the grain, and a change of the color from blue to white, and the development of graphite, complex silicates, and heavy oxides. Pyroxenes, amphiboles, feldspar, epidote, quartz, scapolite, magnetite, spinel, and many others are more or less common developments. There is also a notable series of sulphides, among them mispickel, galena, pyrite, molybdenite, orpiment, and realgar. To what extent these new developments represent recrystallization of materials originally present and to what extent infusion of new materials is not clearly determined. Where the limestones have been invaded by basic intrusions and, on a much larger scale, where they have been invaded by the granite gneisses, they have been altered either to a granular aggregate of pyroxenes and hornblende, with scapolite and accessory minerals, or to a feather-like aggregation of hornblende with other silicates and residual calcite and dolomite. To these rocks, approximating the composition of diabase, the name of amphibolites have been given. The granite gneisses are also full of amphibolite inclusions most of which probably represent altered limestones. From a comparison of the composition of three amphibolites, representing different stages of the alteration of limestones by granite gneiss intrusion, the authors conclude that the process of

amphibolitization involves first a loss of carbonates and a development of feldspar and pyroxene in their stead. In the second stage all carbonates are replaced by pyroxene, feldspars, and scapolite, and finally the rock becomes in texture like a fine-grained igneous rock composed of feldspars, hornblende, and pyroxene. Without presenting analyses of the fresh limestones, the authors assume that this change involves loss of lime and carbonic acid from the limestones and transfusion of silica, alumina, iron, and magnesia with some alkali and titanitic acid from the granite to the limestones. From the data presented this conclusion is only valid if the change took place without loss of mass. The limestones and dolomites are also altered in many places to serpentine marbles. Microscopic studies show, however, that the change to serpentine is preceded by the development of other silicates such as pyroxenes and amphiboles.

The gabbros and diorites occur either as stock-like masses piercing the limestones and altering them to amphibolite, or as dikes cutting the limestones, and as sheet-like masses whose relation to the limestone is uncertain. Some of the latter may be altered pyroclastics. The dikes and sheets have the character of granular amphibolites.

Relatively small masses of acid volcanic orthophyre with distinct flow structures are intercalated with the limestones.

The nepheline corundum-bearing syenites occur between the granite gneisses and the limestone and with one exception within the limestones, thus seeming to corroborate Daly's hypothesis of the genetic relationship of syenites to limestones. All contain limestone inclusions. Certain phases consist largely of nepheline with few femic constituents, others almost entirely of femic minerals, while in some plagioclase feldspar is the dominant mineral.

The greatest petrographic unit of the area, the granite gneisses, presents three principal phases. About 82 per cent of its area, the red gneisses, is composed mainly of oligoclase, with some potash feldspars, quartz and femic accessories; the remainder of the area consists of gray gneisses, high in femic constituents, and amphibolite inclusions, derived mainly from the metamorphosed invaded limestones. The amphibolite inclusions vary in extent from acres to minute lenses, and present all stages of dissolution. Some are still angular and massive, others are pierced by pegmatitic phases of the granitic magma, while pieces which have flowed many feet from each other are separated by fine-grained gneiss. Clear cases of the solution of the amphibolites in the granites, while uncommon, suggest that some of the gray gneisses may have developed in this way. In general, however, the amphibolite inclusions

have not become gneissose, and were much more brittle than the relatively plastic granite gneisses in which they flowed.

A minor occurrence of very acid gneissic red granite, consisting dominantly of potash feldspar and quartz, was found to contain nodules and small vein-like masses of zonally arranged quartz sillimanite and tourmaline, which are regarded by the authors as acid differentiates and not as inclusions.

The alignment of the granite gneiss batholiths with the major axis of folding, and the parallelism of the foliation and folding of both sediments and intrusions, indicates that the invasion of the granite gneisses and the deformation of the region was largely contemporaneous. Intrusion was effected by the up-bowing of the sediments, and by the invasion of the magma as a pegmatitic facies into the shattered sedimentary border zone, or by *lit-par-lit* intrusion, followed by the stopping-off of the intruded rocks into the magma. Solution of the sediments was a very subordinate process.

The authors believe that the granite gneisses were in a partially crystallized but pasty condition when injected, as shown by their flow lines, the granulation of the feldspars, and the elongation of the more plastic quartz crystals. While most of the deformation of the granite gneisses took place without fracturing, other than the granulation of mineral particles, some of the sharp folds grade into faults, or shear zones which are invariably filled with granite pegmatite. Many of the granite pegmatitic veins in shear zones and in the border zones of the sediments were intruded before deformation was completed, and became granulated and sheared into pseudoconglomerates, while others were injected after deformation was completed and show no fracture or distortion.

The principal exploited economic mineral of these areas is corundum from the syenites. Gold and copper-bearing veins are also known to dissect the amphibolites, while magnetite is found as a segregation in the syenites and in bands in the stratified amphibolites. Apatite and graphite-bearing pegmatites cut the limestones, and graphite also occurs in lenses parallel with the stratification of the limestones. Post-glacial deposits of marl and ochre have been located, and building stones in the form of marble, serpentine marble, and sodalite are described as valuable but as yet undeveloped resources.

This report is rich in illustrative and descriptive information on the mechanics of intrusion, the adjustment of materials to stress strain conditions, magmatic differentiation, and on contact metamorphism. If anything, it may be mildly criticized for too much detail. In order

to get at the essentials, the reader is often obliged to skim over many superfluous details on the optical properties of minerals. Some of the important conclusions may be open to the objection that they are based on insufficient evidence; namely, the great thickness and conformability of the sedimentary series, and the transfusion of certain materials from the granite gneisses to the limestones.

EDWARD STEIDTMANN

[*Author's Abstract*]

Production of Graphite in 1911. By EDSON S. BASTIN. Advance chapter from Mineral Resources of the United States, 1911. U.S. Geological Survey.

The natural graphite mined and concentrated in the United States is variable in amount, principally because the process of milling flake graphite, the most abundant type of domestic material, is still in an experimental stage. Because of this unreliability of the domestic supply most of the large consumers of graphite prefer to depend for their supply on imported material.

In 1911 the quantity of graphite imported into the United States for consumption was 20,702 short tons, valued at \$1,495,729. In contrast to this the total domestic production was 3,618 short tons of natural graphite, valued at \$288,465, and 5,072 short tons of manufactured graphite, valued at \$664,000.

The great bulk of the graphite imported into the United States comes from the island of Ceylon, and the United States has for many years been the principal market for this Ceylon product. Considerable amounts of graphite are also imported into the United States from Mexico and within the last few years graphite from Chosen (Korea) has entered the market.

The principal feature of this report as distinguished from previous reports on the production of graphite in the United States is a summary of existing knowledge in regard to the famous graphite deposits of the island of Ceylon. The literature concerning these deposits is widely scattered, mostly in obscure publications. The geological occurrence of the Ceylon graphite, method of working the deposits and of preparing the graphite for the market are discussed, and the various theories which have been advanced to account for their origin are summarized. A list of the principal publications dealing with these deposits is included.

The report also describes a somewhat similar occurrence of graphite near Dillon, Mont., and concludes with a bibliography of all of the important publications dealing with the graphite deposits of the United States.